

# GCRT J1742-3001: A New Radio Transient towards the Galactic Center

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## ABSTRACT

We report the detection of a new transient radio source, GCRT J1742–3001, located  $\sim 1^\circ$  from the Galactic center. The source was detected ten times from late 2006 to 2007 May in our 235 MHz transient monitoring program with the Giant Metrewave Radio Telescope (GMRT). The radio emission brightened in about one month, reaching a peak observed flux density of  $\sim 100$  mJy on 2007 January 28, and decaying to  $\sim 50$  mJy by 2007 May when our last monitoring observation was made. Two additional faint, isolated 235 MHz detections were made in mid-2006, also with the GMRT. GCRT J1742–3001 is unresolved at each epoch, with typical resolutions of  $\sim 20'' \times 10''$ . No polarization information is available from the observations. Based on nondetections in observations obtained simultaneously at 610 MHz, we deduce that the spectrum of GCRT J1742–3001 is very steep, with a spectral index less than about -2. Follow-up radio observations in 2007 September at 330 MHz and 1.4 GHz, and in 2008 February at 235 MHz yielded no detections. No X-ray counterpart is detected in a serendipitous observation obtained with the X-ray telescope aboard the *Swift* satellite during the peak of the radio emission in early 2007. We consider the possibilities that GCRT J1742–3001 is either a new member of an existing class of radio transients, or is representative of a new class having no associated X-ray emission.

*Subject headings:* Galaxy: center — radio continuum — stars: variable: other

## 1. Introduction

Many astronomical sources exhibit transient radio emission including flare stars, brown dwarfs, masers, gamma-ray bursts, pulsars, supernovae, active galactic nuclei, and neutron star and black hole X-ray binaries. Unfortunately, there have only been a few blind radio surveys that have searched efficiently for radio transients, due to one or more limitations including inadequate field of view, collecting area, observing time, bandwidth, or time resolution. Therefore, most radio transients have been found through monitoring observations of known or suspected transient emitters. Recent improvements in low-frequency and wide-field imaging techniques, particularly at lower frequencies (LaRosa et al. 2000; Nord et al. 2004), are enabling more efficient searches for transient emission in the radio sky. Consistent with the expectation that previous limitations on the detection of radio transients

were instrumental and not astrophysical, recent radio transient monitoring programs are revealing potentially new types of astronomical sources including rotating radio transients (McLaughlin et al. 2006), periodic, coherent bursts from an ultracool dwarf (Hallinan et al. 2007), an extragalactic 30 Jy millisecond burst (Lorimer et al. 2007), several 1-3 Jy radio bursts reported at high and low Galactic latitudes (Niinuma et al. 2007; Matsumura et al. 2007; Kida et al. 2008), and ten milliJansky transients detected in 22 years of archival VLA observations of a single field of view at 5 and 8.4 GHz (Bower et al. 2007).

Over the past several years, we have conducted a blind search for radio transients in the Galactic center (GC) at 235 and 330 MHz using archival VLA observations made between 1989 and the present, and monitoring observations with both the VLA and GMRT beginning in 2002. Our motivation is that the naturally wide fields of view obtained at lower frequencies combined with the high stellar densities toward the GC provide an efficient means for searching for radio transients. We detected two radio transients, GCRT J1746-2757 (Hyman et al. 2002) and GCRT J1745-3009 (Hyman et al. 2005, 2006, 2007; Kaplan et al. 2008), for which no counterpart has been detected at high energies, and therefore would not have been detected in the more conventional manner of following up newly discovered X-ray or  $\gamma$ -ray transients. These two radio transients have markedly different observed properties. GCRT J1746-2757 was detected in a single 330 MHz, 7-hr observation in 1998 with a constant  $\sim$ 200 mJy flux density, while GCRT J1745-3009 emitted five  $\sim$ 1 Jy,  $\sim$ 10 minute-long bursts every 77 minutes in a 330 MHz observation in 2002, and a single, weaker burst in each of two subsequent observations in 2003 and 2004. The properties of GCRT J1745-3009, discussed in detail in Hyman et al. (2007), suggest strongly that unlike most radio transients which are incoherent synchrotron emitters, GCRT J1745-3009 is a member of a new class of coherent emitters.

This paper reports the discovery of another low frequency radio transient, GCRT J1742–3001, detected at 235 MHz in our 2006-2007 monitoring program with the Giant Metrewave Radio Telescope (GMRT). The source is not detected in X-ray observations obtained with the X-ray telescope (XRT) aboard *Swift* taken in early 2007 during the peak of the radio emission. Its temporal evolution is similar to that for the bright radio transient, the Galactic Center Transient (GCT), which also has not been detected at high energies (Zhao et al. 1992). We present the observations and results on GCRT J1742–3001 in Section 2, and discuss similarities to the GCT and constraints on possible models in Section 3.

## 2. Observations and Results

### 2.1. Radio Detection

Our 2006-2007 GMRT monitoring program of the Galactic center consists of twenty-one simultaneous 235 and 610 MHz observations, each 2 to 5 hr long, for a total observing time on source of 66 hr. The observations were pointed towards the bursting Galactic center radio transient, GCRT J1745-3009, in order to monitor it for renewed activity (none was detected) while at the same time searching for serendipitous new transients enabled by the large GMRT field-of-view at 235 MHz (2.0° FWHM).

Initial calibration and imaging was performed in a manner similar to that described in Hyman et al. (2006). Amplitude calibration was conducted in reference to 3C286 and phase calibration was based on observations of the nearby source J1830-360. A polyhedral imaging algorithm was employed to compensate for the non-coplanarity of the GMRT at low frequencies (Cornwell & Perley 1992) and several iterations of imaging, deconvolution, and self-calibration were used.

The new transient radio source, GCRT J1742–3001, reported in this paper is derived from the 235 MHz GMRT monitoring observations, which are listed in Table 1. Figure 1 shows GCRT J1742–3001 located 0.1° above the Galactic plane and 1.25° southwest of Sgr A\*, toward the Sgr E complex of compact sources. Figure 2 shows the light curve of GCRT J1742–3001, including  $3\sigma$  upper limits for nondetections. The source exhibited potentially multiple short bursts (epochs 2006 June 13, 2006 July 17, and possibly 2006 November 16), of a duration no more than about 10 days, followed by a long burst beginning on 2007 December 17 and continuing until at least 2007 May 15 when our 2007 monitoring campaign ended. This last burst appears to have a fast rise, reaching the peak in about 1 month, and then decaying over the next 4 months. The peak measured flux density ( $107.9 \pm 8.4$  mJy) occurred on 2007 January 28. No polarization information is available from the observations. A correction of  $1.37 \times$  for primary beam attenuation at the location of GCRT J1742–3001 has been applied to the flux densities, and additional corrections are discussed below.

GCRT J1742–3001 is unresolved at a nominal resolution of  $\sim 20'' \times 10''$  obtained at each epoch. Fitting an elliptical Gaussian, along with a background level, to the source yields an average position and  $1\sigma$  uncertainty of (J2000)  $17^{\text{h}} 42^{\text{m}} 4.67^{\text{s}}$  ( $\pm 0.57^{\text{s}}$ ),  $-30^{\circ} 01' 44.5''$  ( $\pm 2.5''$ ). This position includes corrections for ionospheric refraction which is prevalent at low radio frequencies. To determine these corrections, we first measured the position at each epoch of the bright extragalactic source, Sgr E18 (Gray et al. 1993; Cram et al. 1996), located only  $\sim 5'$  south of GCRT J1742–3001 and visible on Figure 1. We then subtracted the average

of these positions from the average of the 6 and 20 cm positions of this source determined in the reanalysis by White et al. (2005) of their Galactic plane radio survey of 586 compact sources (Zoonematkermani et al. 1990; Helfand et al. 1992; Becker et al. 1994). The resulting differences of  $+0^{\circ}71 \pm 0^{\circ}43$  in right ascension and  $-3.2'' \pm 1.6''$  in declination were applied to the average position obtained for GCRT J1742–3001, yielding the corrected position given above. As a check, we also followed the same procedure for the bright source, Sgr E46, located further from GCRT J1742–3001 as indicated on Figure 1. In principle, ionospheric refraction could be position dependent over the large field of view at 235 MHz, but we find the position correction for Sgr E46 to be consistent with that for Sgr E18.

Based on our experience with the bursting transient GCRT J1745–3009 (Hyman et al. 2005), we also searched for flux density variations within the scans comprising each day’s observation of GCRT J1742–3001. A typical observation consisted of numerous scans, each approximately 30 minutes in duration. On 2007 February 28, the flux density measured for the third scan is  $107 \pm 12$  mJy, a  $3.3\sigma$  marginal variation in comparison to the 68 mJy average of the other six scans. No significant variation is found on shorter timescales within the third scan, and no other scan-to-scan marginal variations are detected at this or any of the other epochs.

The error bars in Figure 2 reflect the rms noise levels ( $\sim 3\text{--}10$  mJy beam $^{-1}$ ) of the images near the location of GCRT J1742–3001 and a 5% uncertainty in the absolute calibration of each data set added in quadrature. The latter was determined by comparing, from epoch to epoch, the flux densities of known bright sources located near GCRT J1742–3001 that should be constant in time. In the process, we discovered that the flux densities of these field sources varied significantly, but approximately in unison, due to an instrumental effect (the increase in system temperature from the calibrator field to the target) which has been encountered by other GMRT observers (e.g., Roy & Rao (2004)). Following the approach of van der Horst et al. (2008), we therefore applied a relative correction to GCRT J1742–3001 tied to the flux density of the relatively bright extragalactic source Sgr E46 (indicated on Figure 1) determined for each epoch and at the peak of the emission from GCRT J1742–3001 on 2007 January 28. The correction factors range from 0.4 to 2.1 and are provided in Table 1. As a check, we also corrected the flux densities of the nearby source Sgr E18, mentioned above, on which we based the position correction. The residual epoch to epoch variations are at the  $\sim 5\%$  level for this source, and we therefore include this relative calibration correction uncertainty in the error bars of Figure 2.

To determine an overall calibration correction to apply to the light curve of GCRT J1742–3001, we used a separate 235 MHz observation provided by S. Roy from a separate program (Roy & Rao 2006), but which does not suffer from absolute calibration limitations. The latter

observation was pointed  $1.2^\circ$  north of the monitoring observations, and so the region containing GCRT J1742–3001 and the Sgr E complex lies outside the FWHM of the primary beam. We chose a bright source (TXS 1745-296) located at the half-power point of both primary beams as the most suitable source on which to base the overall correction. The ratio of the flux density of TXS 1745-296 (0.6 Jy) to that measured from our observation of 28 January 2007 was determined to be 1.43, and was used to further correct the flux densities of GCRT J1742–3001. Both the relative epoch to epoch and overall corrections are reflected in the light curve of Figure 2. The error bars, however, do not include an additional  $\sim 5\%$  uncertainty in the overall correction of the light curve in order to not mask the relative changes from epoch to epoch.

We searched for GCRT J1742–3001 in our simultaneous GMRT observations acquired at 610 MHz, but were unable to detect it at any epoch. The location of GCRT J1742–3001 is  $40.0'$  from the phase center of the observations; this is far outside the  $44'$  field of view (FWHM) at 610 MHz where the primary beam attenuation is much greater than the attenuation factor of 1.4 at 235 MHz. Models of the primary beam pattern do not provide reliable correction values at such extreme distances from the phase center. However, in principle, a correction factor can be estimated, and hence, also the upper limit on the flux density of GCRT J1742–3001, by using the ratio of the measured to the actual flux density of a field source located sufficiently near to GCRT J1742–3001. While we were unable to obtain any such known 610 MHz flux densities, we were able to estimate the 610 MHz flux density of the nearby source, Sgr E18, from a power law fit to the flux densities available at 330, 1281, 1658, and 4850 MHz (Nord et al. 2004; Lazio & Cordes 1998), together with the average flux density determined from our 235 MHz observations (which varied by only  $\sim 5\%$ , as discussed above). Sgr E18 is detected in our 610 MHz observations at the  $20\sigma$  level, and is fortuitously located only  $\sim 5'$  south of GCRT J1742–3001 and at nearly the same angular distance ( $39.6'$ ) from the phase center of the observations. This close proximity mitigates against the inaccuracies associated with the asymmetries and high radial dependence of the primary beam correction known to exist far outside the nominal field of view; hence, we could apply the correction obtained for Sgr E18 to the noise level of the image in order to estimate an upper limit for the 610 MHz flux density of GCRT J1742–3001.

The power law fit ( $S \propto \nu^\alpha$ ) to the flux densities of Sgr E18 yields a spectral index of  $\alpha = -0.87 \pm 0.08$ , and a predicted flux density of  $225 \pm 20$  mJy at 610 MHz. The measured flux density of Sgr E18 at 610 MHz from the 28 January 2007 epoch (the date of the peak emission at 235 MHz) is  $14.5 \pm 0.8$  mJy, leading to a correction factor of  $15.5 \pm 1.6$ . (Note that this factor accounts for the primary beam attenuation and also any absolute calibration error that might exist in the 610 MHz data analogous to that discussed above for the 235 MHz observations.) We applied this correction to the  $0.31$  mJy beam $^{-1}$  rms noise level of

the uncorrected image. The 610 MHz  $3\sigma$  upper limit for GCRT J1742–3001 is therefore  $\sim 15$  mJy on 2007 January 28, compared to the 107 mJy detection at 235 MHz obtained for that epoch. This result yields a spectral index constraint of  $\alpha \lesssim -2$ . We also attempted to determine the spectrum of GCRT J1742–3001 by looking for any change across the 6-MHz bandpass of the 235 MHz observations. A power law fit results in a largely unconstrained spectral index of  $\alpha = 0 \pm 5$ .

GCRT J1742–3001 is not detected in follow-up observations at 330 MHz (VLA) and 1.4 GHz (GMRT) in 2007 September, with  $3\sigma$  upper limits of 30 mJy and 0.9 mJy, respectively. If the source was still active during these observations with a 235 MHz flux density of  $\sim 50$  mJy, then the spectral index of the source at that time would have been steeper than  $\alpha = -2$ . However, GCRT J1742–3001 could also have faded significantly from when it was last detected in 2007 May. Unfortunately, we could not obtain follow-up GMRT observations at 235 MHz until 2008 February 7 when the source was not detected, with a  $3\sigma$  upper limit of 36 mJy.

In addition to our 235 MHz GMRT monitoring program, we also monitored the Galactic center with the VLA at 330 MHz during 2006, but not 2007. The VLA program, which will be presented in detail in a subsequent paper, consisted of twenty observations from 2006 February to 2006 September, each  $\sim 2.5$  hr in duration, for a total of  $\sim 50$  hr. GCRT J1742–3001 was not detected in any of the epochs, although one of the 2006 observations occurred on 2006 June 13, the same date as when the GMRT detected the transient with a 33 mJy flux density at 235 MHz. Unfortunately, the VLA  $3\sigma$  upper limit of 45 mJy barely constrains the spectral index between 235 and 330 MHz ( $\alpha < +0.9$ ). However, following the method described above, we estimate an upper limit of  $\sim 10$  mJy for the 610 MHz flux density for the 2006 June 13 epoch, which, given the 235 MHz value, corresponds to a spectral index constraint of  $\alpha \lesssim -1.3$ .

An image made from the combination of our 2006 VLA 330 MHz observations did not detect the source with a  $3\sigma$  upper limit of 10 mJy. The upper limit obtained by combining our 235 MHz nondetection observations from 2006 is also 10 mJy.

## 2.2. X-ray Nondetection

On 2007 February 2, the *Swift* satellite serendipitously pointed with the XRT for  $\sim 190$  seconds towards the region of the radio transient. No X-ray source was detected in the field-of-view of the XRT. Using the Bayesian confidence limit method (Kraft, Burrows, & Nousek 1991) we calculated a  $3\sigma$  upper limit on the count rate of 0.038 counts/s (for the

energy range 0.3-10 keV) at the position of the radio transient.

To convert this count rate upper limit to a flux upper limit we used WebPIMMS<sup>1</sup> and we assumed an absorbed power law spectrum with a column density<sup>2</sup>  $N_h = 1.3 \times 10^{22} \text{ cm}^{-2}$  and a photon index of 2. This resulted in upper limits on the 2-10 keV absorbed flux of  $2.3 \times 10^{-12} \text{ erg cm}^{-2} \text{ s}^{-1}$  and an unabsorbed flux of  $2.5 \times 10^{-12} \text{ erg cm}^{-2} \text{ s}^{-1}$ . For a harder spectrum (photon index  $\sim 1$ ) these values are around 70% larger. If the source is located near the Galactic center at a distance of  $\sim 8.5$  kpc, then the upper limit on the 2-10 keV luminosity would be  $\sim 2.2 \times 10^{34} \text{ erg s}^{-1}$ , assuming a photon index of 2.

In addition to the 2007 February 2 observation, *Swift* was pointed at the source direction on four additional occasions from 2005 to 2008 listed in Table 2. We combined all five data sets but still the source was not detected. The  $3\sigma$  upper limit for the combined data set is 0.010 counts/s. Assuming the same spectral shape as above, the absorbed flux upper limit (2-10 keV) would then be  $5.9 \times 10^{-13} \text{ erg cm}^{-2} \text{ s}^{-1}$  and the unabsorbed flux limit would be  $6.7 \times 10^{-13} \text{ erg cm}^{-2} \text{ s}^{-1}$ . For a distance of 8.5 kpc, the 2-10 keV luminosity upper limit would be  $5.5 \times 10^{33} \text{ erg s}^{-1}$ .

### 3. Discussion

We have searched the environment of GCRT J1742–3001 for associated discrete sources or extended structures. GCRT J1742–3001 is located in the Sgr E complex of discrete sources, many of which have a flat spectrum and are confirmed by recombination line observations to be HII regions (Cram et al. 1996; Gray et al. 1993). The closest source is Sgr E19, which is faintly visible about 2' south of GCRT J1742–3001 on Figure 1. This source is described as a possible candidate young supernova remnant in Cram et al. (1996). However, more extensive observations and the detection of counterpart infrared sources (Misanovic, Cram, & Green 2002) indicate that Sgr E19 is much more likely to be a HII region and that it is not associated with Sgr E, but rather is much closer to us. Whether GCRT J1742–3001 is within the Sgr E complex or is also much closer remains to be seen. We see no other nebulosity on radio images of this region that appears to be connected to GCRT J1742–3001, although there are several 2MASS infrared sources located within the  $3\sigma$  positional error ellipse, the nearest 10'' away from GCRT J1742–3001.

We have used the upper limit to the angular size of GCRT J1742–3001 to constrain its

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<sup>1</sup><http://heasarc.gsfc.nasa.gov/Tools/w3pimms.html>

<sup>2</sup><http://heasarc.gsfc.nasa.gov/cgi-bin/Tools/w3nh/w3nh.pl>

brightness temperature. Additional Gaussian fits were made to the 2007 January 28 detection, with the major and minor axes varied until the fit returned an integrated flux density  $1\sigma$  above the nominal integrated flux. The corresponding upper limit on the geometric mean of the deconvolved major and minor axes (FWHM) is  $8''$ . In turn, this implies a lower limit on its brightness temperature of  $1.2 \times 10^4 K$ . Since this is a conservative estimate, we conclude that GCRT J1742–3001 is likely nonthermal, which is also consistent with the steep spectrum determined in Section 2.1.

### 3.1. Similarity to the Galactic Center Transient

The temporal evolution of GCRT J1742–3001 is similar to that for the GCT which was detected in monitoring observations of Sgr A\* from late 1990 December until late 1991 September at radio wavelengths from 1.3 to 22 cm (Zhao et al. 1992). The GCT reached its maximum in approximately one month and faded with a time scale of about three months. In Figure 3 we show exponential fits to the rising and decaying portions of the light curve of GCRT J1742–3001. The rise and decay time constants resulting from the fits are  $34 \pm 10$  days and  $102 \pm 38$  days, respectively, and the date of the peak flux density determined is 2007 January  $28 \pm 5$  days. A power law  $S \propto t^{-\beta}$  fit to the six detections from 2007 January 28 through 2007 May 15 yields an index of  $\beta = 0.60 \pm 0.14$ , similar to that obtained ( $0.67 \pm 0.08$ ) for the decay portion of the light curve of the GCT.

The GCT had a  $\sim 1$  Jy peak flux density in the wavelength range 18-22 cm ( $\sim 1.5$  GHz), and a relatively constant and steep spectral index of  $\alpha = -1.2$  over the duration of the transient emission. GCRT J1742–3001 has a  $\sim 100$  mJy peak at 235 MHz and also has a steep spectrum with  $\alpha \lesssim -2$  calculated between 235 and 610 MHz. Assuming the spectral index is constant, the corresponding 1.5 GHz upper limit is  $\sim 2.5$  mJy, or about  $400 \times$  fainter than the GCT. However, the distance to GCRT J1742–3001 is unknown, whereas Zhao et al. (1992) determined that the GCT is located at the Galactic center, about 8.5 kpc distant; if GCRT J1742–3001 is located much closer to us than the GC, its luminosity could be even smaller compared to the GCT.

Extrapolating the 1.5 GHz flux density upper limit for GCRT J1742–3001 with either the exponential or power law fits yields flux densities which are consistent with our 1.5 GHz nondetection on 2007 September 19, described earlier. We note, though, that the GCT exhibited a significant secondary maximum in the 18-22 cm observations about 6 months after the primary. If GCRT J1742–3001 also emitted a secondary maximum and it occurred during the second half of 2007 when we were no longer monitoring, our sparse follow-up radio observations in 2007 September and 2008 February might very well have

missed this additional activity. Similarly, it is possible that the weaker flux densities recorded on 2007 March 24 and 2006 December 17 (see Figure 2) are indicative of broad secondary maxima extending before and/or after our observations on 2006 November 16 and 2007 May 15, respectively. However, it is also possible that these low data points are just short fluctuations in the light curve, as was also seen in the light curve of the GCT up to the 50% level. Importantly, the two detections in mid-2006 demonstrate the recurrence of transient emission from GCRT J1742–3001, although it is not clear how and/or whether these fainter detections are related to the primary emission in 2007.

Based on its radio and infrared properties, Zhao et al. (1992) suggest that the GCT is a synchrotron-emitting radio transient associated with an X-ray binary system. Indeed, the duration of the radio outburst from the GCT (and from GCRT J1742–3001) is similar to those observed for X-ray outbursts from accreting black hole systems. But while the *Swift* X-ray nondetection of GCRT J1742–3001 significantly constrains the level of any X-ray emission from it, there are unfortunately no reports in the literature of X-ray emission upper limits for the GCT. Without such information, we cannot determine if the temporal similarities of GCRT J1742–3001 and the GCT are merely coincidental, or if the two transients are actually similar in nature, in which case the interpretation of the GCT as an X-ray binary system might need to be reexamined.

### 3.2. X-ray Model Constraints

For the majority of black hole X-ray binaries a 'universal correlation' has been seen between the radio and X-ray luminosities of the systems (Corbel et al. 2003; Gallo, Fender, & Pooley 2003). Assuming the relation found by Gallo, Fender, & Pooley (2003) for much higher frequencies (4.9 to 15 GHz) is valid at 235 MHz, our  $\sim$ 100 mJy peak flux density corresponds to a predicted 2-11 keV X-ray flux of  $(0.5 - 2) \times 10^{-8}$  erg cm $^{-2}$  s $^{-1}$  for GCRT J1742–3001 if it is located at 1 kpc, or  $(0.3 - 1) \times 10^{-7}$  erg cm $^{-2}$  s $^{-1}$  if the distance towards the source is 8.5 kpc. This is  $\sim$ 4 orders of magnitude brighter than the X-ray upper limit we deduced in Section 2.2 for GCRT J1742–3001. Although a number of outliers have been identified which do not follow this correlation, they are always under luminous in the radio compared to their X-ray luminosity and not under luminous in the X-ray.

We note, however, that black hole X-ray binaries in low luminosity states typically have flat radio spectra (Fender 2001), which we do not find is the case for GCRT J1742–3001. Instead, and as described in Section 2.1, we find the source apparently has a very steep radio spectrum towards lower frequencies. The GHz flux density is therefore probably much lower than that observed at 235 MHz, which in turn would significantly lower the inferred X-ray

flux. Indeed, taking the upper limit of the spectral index of GCRT J1742–3001 ( $\alpha = -2$ ) to extrapolate the flux density to 4.9 GHz, yields a corresponding X-ray flux upper limit approximately equal to the upper limit of the *Swift* observation. Therefore, it is possible that GCRT J1742–3001 is a black hole binary and that, instead of being in a low luminosity state, the source did emit a faint, undetected X-ray outburst during our radio detection. We underscore, though, that our constraint on the radio spectrum of GCRT J1742–3001 is determined only from the 235 MHz detection and 610 MHz nondetection. If the spectral index is not uniform, then depending on the extent to which it flattens toward higher frequencies, we might have been able to detect an X-ray outburst.

Alternatively, the low-frequency radio emission could have had a significant delay with respect to a possible undetected bright X-ray outburst. However, in that case the radio spectrum should also steepen toward lower radio frequency since if this was not the case the associated X-ray flux would be very high. It is unlikely that such a bright X-ray outburst would have gone unnoticed by the X-ray monitoring instruments in orbit especially if the X-ray outburst had a similar duration as the radio outburst. Perhaps the simplest explanation is to assume that the new radio transient is not an accreting black hole at all, although it might also be one of the first of a group of accreting black holes which are radio bright and very under-luminous in the X-ray.

Alternatively, the new radio transient might be an accreting neutron star, but since such systems are fainter in the radio with respect to their X-ray fluxes compared with the accreting black holes, the discrepancy between the expected and observed X-ray fluxes would even be larger than for the black holes.

In summary, we have detected a new low frequency radio transient, GCRT J1742–3001, with the GMRT which is the third X-ray quiet transient found in our Galactic center radio monitoring program. Each of these transients exhibited markedly different observational properties: (1) single epoch detection at 330 MHz (GCRT J1746-2757); (2) repeated, and possibly coherent, bursts over a six hour 330 MHz observation and fainter single bursts within the subsequent two years (GCRT J1742-3009); and (3) multiple detections at 235 MHz, including one possible 25 min. coherent burst, brightening and fading over a period of six months, with a steep spectrum (GCRT J1742–3001).

Continued radio monitoring of these transients and multi-wavelength follow-up observations are necessary to identify their emission mechanisms and to determine whether they are examples of new populations of astronomical objects or are related in a hitherto unknown way to existing source classes.

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Table 1. 235 MHz GMRT Observations of GCRT J1742–3001

Epoch	Duration (hr)	Rel. Calib. Factor	Resolution ( $''$ )	Flux Density <sup>a</sup> (mJy)
2006 March 01	3.0	0.99	$15.5 \times 10.2$	5.1 <sup>b</sup>
2006 March 08	3.3	2.12	$17.6 \times 9.4$	4.6 <sup>b</sup>
2006 April 2-3	3.5	0.64	$15.5 \times 10.0$	5.4 <sup>b</sup>
2006 June 13	4.0	0.53	$26.9 \times 9.4$	$32.7 \pm 6.7$
2006 June 29	2.4	2.14	$20.4 \times 11.0$	12.2 <sup>b</sup>
2006 July 09	2.6	0.78	$18.6 \times 10.2$	6.5 <sup>b</sup>
2006 July 17	3.0	0.83	$17.2 \times 9.3$	$64.6 \pm 4.4$
2006 August 18	3.5	0.53	$31.6 \times 12.5$	4.4 <sup>b</sup>
2006 August 19	5.6	0.81	$20.5 \times 9.2$	4.3 <sup>b</sup>
2006 August 26	2.7	0.76	$22.8 \times 9.3$	5.3 <sup>b</sup>
2006 September 16	4.2	1.64	$18.9 \times 12.0$	7.9 <sup>b</sup>
2006 November 16	2.3	0.82	$24.2 \times 11.4$	$68.0 \pm 8.5$
2006 December 17	3.1	0.47	$24.6 \times 8.7$	$35.3 \pm 7.4$
2007 January 07	2.5	0.39	$27.3 \times 9.1$	$56.5 \pm 7.7$
2007 January 16	2.6	0.53	$21.4 \times 8.9$	$65.3 \pm 9.9$
2007 January 28	2.9	1.00	$21.1 \times 9.9$	$107.8 \pm 6.5$
2007 February 12	2.5	1.07	$17.3 \times 9.3$	$96.1 \pm 6.3$
2007 February 28	3.0	0.58	$14.9 \times 10.0$	$77.5 \pm 4.2$
2007 March 24	2.8	0.75	$16.4 \times 9.3$	$37.1 \pm 3.2$
2007 April 2-3	2.7	0.90	$17.5 \times 10.4$	$56.7 \pm 3.5$
2007 May 15	3.9	0.96	$16.5 \times 10.7$	$51.3 \pm 4.9$
2008 February 07	3.2	0.55	$28.6 \times 9.0$	11.8 <sup>b</sup>

<sup>a</sup>The flux densities include an overall calibration correction of  $1.43 \times$  in addition to the relative calibration corrections (see text).

<sup>b</sup>No detection. The rms noise level measured at the location of GCRT J1742–3001 is listed.

Table 2: Upper limits on the 0.3-10 keV X-ray count rates and 2-10 keV X-ray fluxes during five serendipitous *Swift* XRT observations. Fluxes are derived assuming an absorbed power law spectrum with  $\Gamma = 2.0$  and  $N_h = 1.3 \times 10^{22} \text{ cm}^{-2}$ .

Epoch	$T_{\text{exp}}$ (s)	count rate (0.3-10 keV)	absorbed flux ( $\text{erg cm}^{-2} \text{ s}^{-1}$ , 2-10 keV)	unabsorbed flux
2005 May 15	62.6	0.094	$5.6 \times 10^{-12}$	$6.3 \times 10^{-12}$
2005 November 01	456.3	0.019	$1.1 \times 10^{-12}$	$1.3 \times 10^{-12}$
2006 February 07	138.6	0.043	$2.5 \times 10^{-12}$	$2.9 \times 10^{-12}$
2007 February 02	193.1	0.038	$2.3 \times 10^{-12}$	$2.5 \times 10^{-12}$
2008 February 21	113.7	0.067	$4.0 \times 10^{-12}$	$4.5 \times 10^{-12}$
combined dataset	964.3	0.010	$5.9 \times 10^{-13}$	$6.7 \times 10^{-13}$

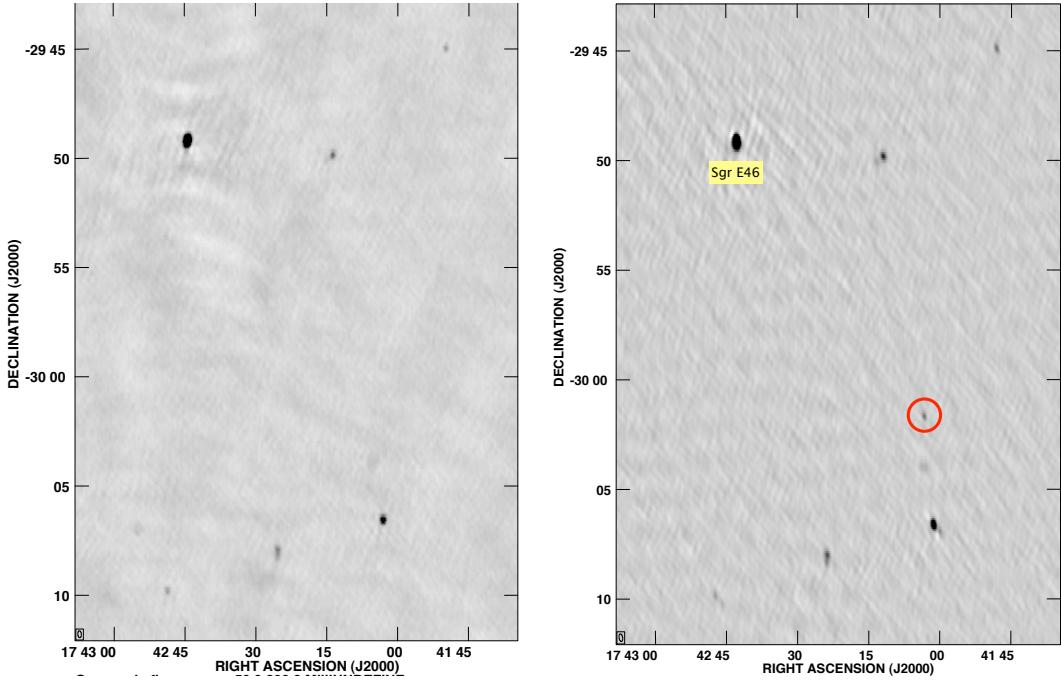


Fig. 1.— 235 MHz GMRT image of the region surrounding GCRT J1742–3001 on 8 March 2006 before detection (*left*) and on 2007 January 28 during the peak of the transient emission (*right*). For the 2006 March 8 image, the rms noise level is  $4.6 \text{ mJy beam}^{-1}$  with a resolution of  $17''.6 \times 9''.4$ ; for the 2007 January 28 image, the rms noise level is  $6.3 \text{ mJy beam}^{-1}$  with a resolution of  $21''.1 \times 9''.9$ . Both observations are approximately 3 hr in duration. For reference, the strong source Sgr E46, used to determine the relative flux density correction for GCRT J1742–3001 at each epoch (see Section 2.1), is labeled in the 2007 January 28 image. The bright source, Sgr E18, located  $\sim 4'$  south of GCRT J1742–3001 was used for astrometric corrections and to double check the relative flux density corrections. The faint source, Sgr E19, located halfway between GCRT J1742–3001 and Sgr E18 is discussed at the beginning of Section 3.

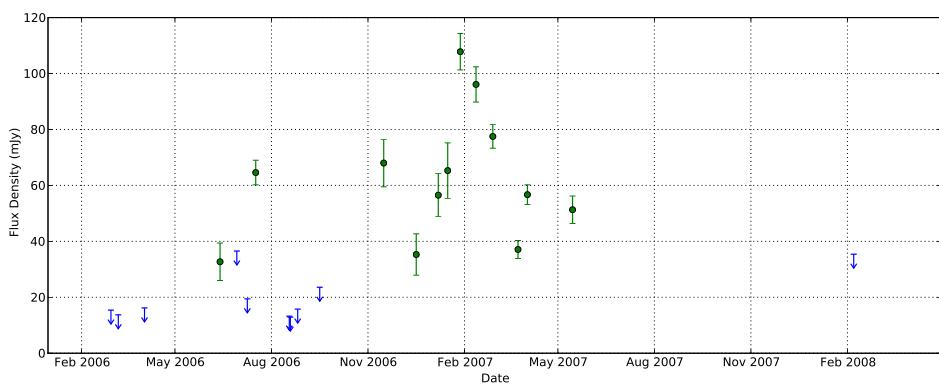


Fig. 2.— The 235 MHz light curve of the GMRT detections (circles) of GCRT J1742–3001 and  $3\sigma$  upper limits.

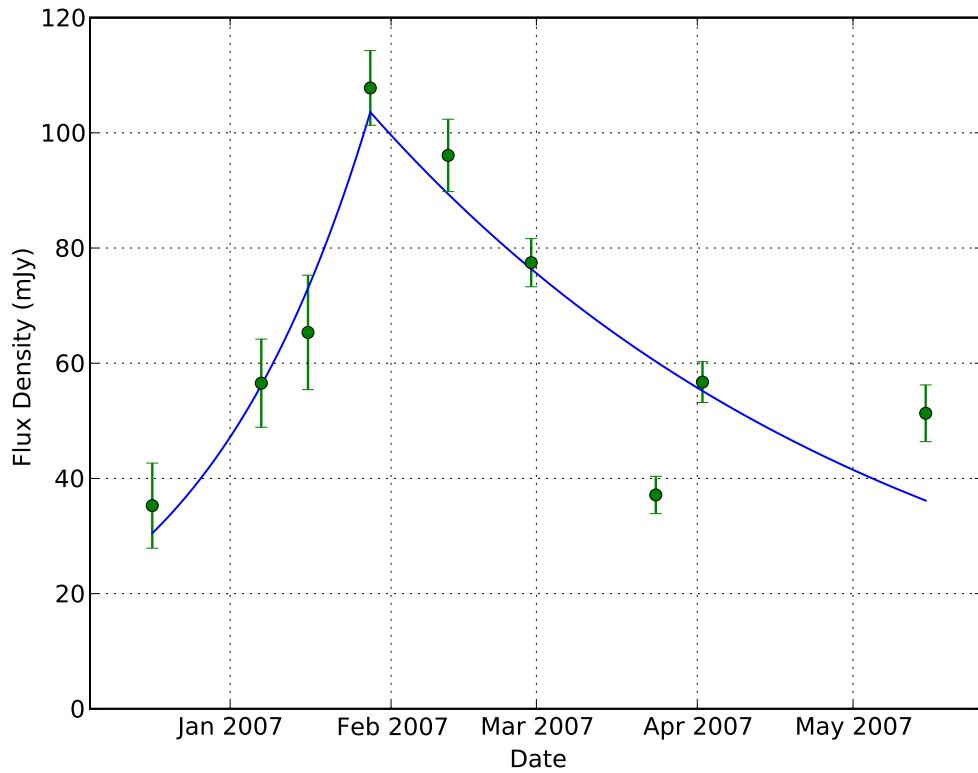


Fig. 3.— Exponential fits to the 235 MHz light curve of GCRT J1742–3001. The rise and decay time constants resulting from the fit are  $34 \pm 10$  days and  $102 \pm 38$ , respectively, and the peak flux density is 28 January 2007  $\pm 5$  days.